Virtual National Laboratory for Heavy Ion Fusion

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HIF News

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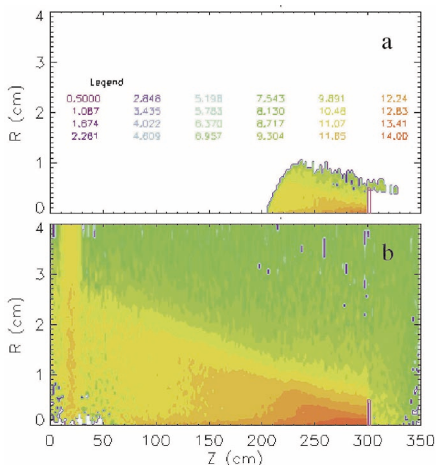
Neutralization of HIF Foot Beams by a Localized Plasma

Focusing the low current (< 1 kA) "foot" pulses to a 1-2 millimeter spot is challenging, and requires significant neutralization of high space charge, which is increased by stripping on chamber gas. Simulations show that main pulses are well charge-neutralized near the target due to ionization of chamber gas by soft X-rays from the heated hohlraum; but foot pulses, which do the initial heating, lack this additional neutralization. We have studied this with the particle-in-cell codes LSP (**L**arge **S**cale **P**lasmas) and BICrz.



BICrz simulations predict that, with neutralization only from impact ionization of gas, the beam focal spot is too large for standard target designs.

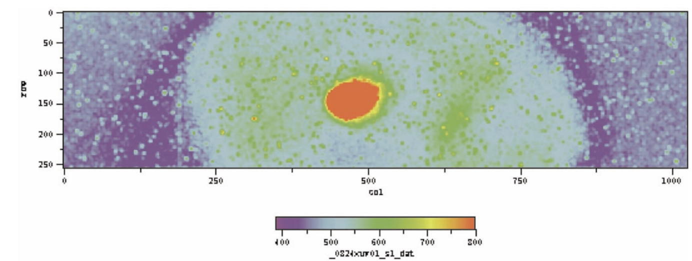
LSP calculations show that plasma near the chamber entrance provides the needed foot-pulse neutralization. The electrons are pulled out of the "plasma plug" as the beam passes and are trapped by the beam electrostatic field. The figure shows (a) a snapshot of the log of the beam density and (b) the electron density after 70 ns of chamber transport in $5x10^{13}$ cm^{-3} flibe. The beam is injected from the left, through a $3x10^{11}$ cm^{-3} plasma at z = 5-15 cm, and strikes the target at z = 300 cm. The beam spot has 90% of beam within 3.3 mm, sufficiently small for a distributed-radiator target. A simulation with $7x10^{12}$ cm^{-3} flibe density produces a spot (90% of beam within 1.9 mm) appropriate for the close-coupled target. Further simulations, including a 3-m entry port, electron emission from metal surfaces, and lower-mass beam ions, are planned soon. *– Dale Welch, William Sharp, David Rose and Simon Yu*

New data advance the study of fast ignition.

Fast ignition separates ignition of a hot spot, from fuel compression, potentially achieving both a higher ratio of fusion burn energy to energy invested in compression (gain) as well as relaxed drive symmetry and pressure requirements. This promise has led to a new concept exploration project in the OFES.

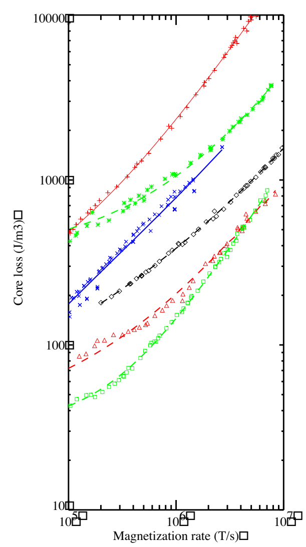
US researchers from LLNL, GA, UC Davis, and Princeton obtained new data on energy transport by laser generated relativistic electrons. They collaborated in experiments at the 50 TW, LULI laser in France and the 100 TW Vulcan laser in the UK. Images of x-ray Kα fluorescence from fluor layers showed that the electron beam expanded in a cone angle of 40° from a minimum spot size of 75 μm. Thermal XUV images of the rear surface of a 100μm Al foil target measured heating to 30eV, as shown in the figure. (A higher temperature of 100 eV, 1% of the ignition requirement, was achieved through a thinner 40 μm foil.) Previous experiments at the LLNL Petawatt laser showed that the efficiency of relativistic electron generation is 30% at ignition relevant intensity.

These data are being used to test and develop numerical models that will evaluate the feasibility of full-scale fast ignition. Conceptual experiments are being devised to use the National Ignition Facility to achieve ignition and high gain. Transitioning to proof of principle studies will be possible with the next generation of high-energy petawatt lasers, which the DOE is planning to build by adapting its high-energy lasers in a National PW Laser Initiative. *– Mike Key*



Alloys and coatings for induction cores

A fusion driver needs ≥10,000 tons of magnetic material in induction cores. This large quantity motivates maximizing performance and minimizing cost. We emphasized performance in evaluating the three types of alloys shown. Each was annealed (at ≥360° C) after winding the core to optimize performance – higher flux swing, lower loss, and better reproducibility. Further work is needed to minimize manufacturing costs.



Two amorphous alloys, METGLAS 2605 SA1(X) and 2605 SC (◊)are low-cost, and provide adequate flux swing (up to 2.7 T) and low losses for acceleration efficiencies near 50% (in a 3.3 MJ, 1.3 GeV Kr+ driver). However, improved insulating coatings are needed for maximum flux swing while blocking interlaminar eddy currents at ~100 ns pulse durations.

Satisfactory coatings are available for nanocrystalline and 3% silicon steel cores. Nanocrystalline alloys have lower flux swings of 2.0(□) to 2.4 T (Δ), but with significantly lower losses that are especially attractive for correction cores – driven by relatively costly pulsers that reduce acceleration field errors to <1%. While currently expensive, the manufacturing technology is similar to that for amorphous alloys with potential for costs of ~$5/kg.

Higher flux swings of 3.0-3.3 T are achieved with 3% silicon steel, in 25um(*) and 50um (+) thicknesses, but with higher losses. Silicon steel is best used near the injector, where it could reduce the core mass by 800 tons while increasing the average pulser power by 0.6 MW (out of 15-30 MW for the entire driver that produces 1000 MW$_e$), but it could also give acceleration efficiencies near 30% for 100 ns pulses. *– Art Molvik and Andy Faltens*

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